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THE MATHEMATICS TEACHER

Volume XXVIII Number 5

Edited by William David Reeve

Transfer of Training and Educational Pseudo-Science*

By PEDRO T. ORATA

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THE French naturalist, Cuvier, was once asked to pass judgment on the following definition: "A crab is a small red fish that walks backward." Cuvier replied: "The definition is entirely correct except at three points,—the crab is not a fish, it is not red, and it does not walk backward." Bagley was in the same predicament a few years ago when he was asked to speak at an N. E. A. meeting on the topic, "Modern Educational Theories and Practical Considerations." In his characteristically satirical mood he developed the proposition beautifully by showing, step by step, that modern educational theory is not modern, that it is not practical, and above all, that it is not educational. We are reminded of these two incidents by the current conception of the problem of transfer of training which is embodied in the phrase, "The Psychology of Transfer of Training." If we were disposed to be facetious we might paraphrase Cuvier and follow Bagley's example by showing, first, that there is no psychology,—there are only psychologies, second, that in a literal sense transfer of training is a myth, and, finally

* Read at the annual meeting of the National Council of Teachers of Mathematics at Atlantic City, N. J. on Friday evening, February 22, 1945.

that the problem of transfer of training is not, educationally speaking, essentially a psychological problem at all. In fact, it is the aim of this paper to attempt a reinterpretation of the problem of transfer of training in the direction of conceiving of it, not as a scientific and more specifically a psychological problem, but fundamentally, though not entirely as an educational and technological question. Hence the title of the article: "Transfer of Training and Educational Pseudo-Science."

I. Brief Summary of Transfer of Training Studies—1927–1935

No attempt will be made here to summarize to any great length the literature on the subject or to announce a new theory of transfer of training. We have on record excellent summaries, both in general[1] and as applied to the school subjects.[2] It will suffice for our purpose to call attention to the statistical results especially with reference to the *amount* and *agencies* of transfer since we made a summary of these in 1927. To date we have on record no less than 167 objective studies, 99 of which were made from 1890 to 1927, and 68 from 1927 to January, 1935. This should impress upon us the fact that far from being dead and buried the problem of transfer of training is more vigorous than ever. That it is so recognized is shown by the tendency to include an extended discussion of the techniques of transfer experiments in recent textbooks on educational research.[3]

The present survey of nearly seventy studies from 1927 to 1935 confirms, in general, the results found by Rugg in 1916[4] and by the writer in 1927.[5] If the results of all studies from 1890 to 1935 are put together, assuming that they possess a fair degree of validity and reliability, we may, with confidence make the follow-

[1] The latest extended summary was made by Dr. Whipple for the *Twenty-Seventh Yearbook* of the National Society for the Study of Education, Part II, p. 179–210, 1928.

[2] Mr. Betz's "The Transfer of Training with Particular Reference to Geometry" in the *Fifth Yearbook* of the National Council of Teachers of Mathematics, p. 149–198 (1930) is an able summary from the point of view of mathematics.

[3] Abelson, H. H. *The Art of Educational Research*, World Book Co., 1933, p. 170–187.

[4] Rugg, H. O., *Experimental Determination of Mental Discipline in School Studies*, Warwick and York, 1916, 132 p.

[5] *The Theory of Identical Elements*, Ohio State University Press, 1928, p. 36–52.

ing generalization: 47 or nearly 30% show *considerable* transfer, 80 or nearly 50% show *appreciable* transfer, 15 or less than 10% show *little* transfer, 6 or less than 4% show *no* transfer, and the rest which comprise less than 10% show both *transference* and *interference*. And since interference is indicative of transfer of a negative character, it is safe to conclude that all doubts with reference to the possibilities of transfer of training may be cast away. Table I shows the results for the 1927–1935 studies and Table II and Fig. 1 indicate corresponding tendencies for the entire period from 1890–1935.

TABLE I

Statistical Results of Transfer Experiments from 1927 to 1935

Findings	Number of Studies			Percent
	Lab.	Class	Total	
Finds considerable transfer	6	9	15	22.1
Finds appreciable transfer	12	19	31	45.4
Transfer varies with conditions of expt.	1	3	4	5.9
Transference and interference	2	2	4	5.9
Finds very little transfer	1	6	7	10.3
Finds no transfer	—	5	5	7.4
Finds interference only	1	1	2	3.0
Total	23	45	68	100.0

With reference to the *agencies* of transfer the results obtained in the 1927 study have been confirmed by the present investigation. In round figures 70% of the studies support the proposition that the effect of practice is general, and that therefore transfer takes place most effectively through *conscious generalization*, whereas about 30% may be classified as supporting the theory that practice is specific and that transfer therefore takes place through *identical elements*. Not an insignificant number of the investigators support both views of *identical elements* and *generalization*. As the saying goes, "When in doubt believe in both."

II. Extending the Frontier of Thinking on Transfer of Training

Even more significant than the essential confirmation of the findings in the 1927 survey of nearly a hundred studies is the enormous gain made in the last seven years in advancing the frontier of thinking which concerns the problem of transfer of training. In the first place, several studies have been made to "test," directly

TABLE II

Statistical Results of Transfer Experiments from 1890 to 1935

Findings	Number of Studies			Percent		
	Lab.	Class.	Total	1890–1927	1927–1935	1890–1935
Considerable transfer	24	23	47	32.3	22.1	28.0
Appreciable transfer	35	45	80	49.5	45.4	48.0
Very little transfer	2	13	15	8.1	10.3	9.0
Finds no transfer	1	5	6	2.0	7.4	3.6
Finds interference	4	1	5	3.0	3.0	3.0
Transfer and interference	10	2	12	8.1	6.0	7.2
Transfer varies with expt'l conditions	3	6	9	5.1	5.8	5.4
Grand Total	79	96	175	108.8	100.0	104.2
Duplication	8	—	8	8.8	—	4.2
Net Total	81	96	167	100.0	100.0	100.0

Note: The figures for 1890–1927 were obtained from Orata, P. T., *The Theory of Identical Elements*, 1928, p. 41.

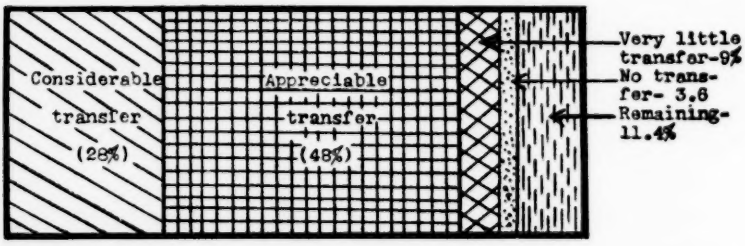

Fig. 1. Graphical Representation of Transfer Experiments from 1890 to 1935.

or indirectly, both of Thorndike's theory of *identical elements* and Judd's theory of *generalization*. It seems fairly conclusive from the results of studies of both human and animal learning that the mere presence of identical elements does not guarantee that transfer takes place.[6] On the other hand, perfect transfer may take

[6] Dorsey, M. F. and Hopkins, L. T., "Influence of Attitude upon Transfer," *Journal of Educational Psychology*, 21:410–17, 1930.

Lehman, H. C., "Class Experiment in the Transfer of Training," *Journal of Applied Psychology*, 17:77–82, 1933.

Alm, O. W., "The Effect of Habit Interference upon Permanence in Maze Learning," *Genetic Psychology Monograph*, 1931, No. 10, p. 379–526. (Summarized in *Psychological Abstracts*, 1932, No. 2209.)

place between two situations which are apparently unrelated.[7] This all goes to show as we have tried to point out in the 1927 survey that transfer may or may not take place depending, not upon the presence or absence of hypothetical identical elements whether they be in terms of content, procedure or even ideal, but upon the extent to which the investigator succeeded in setting up the experiment so as to provide conditions that are favorable to transfer.[8] It is safe to conclude, therefore, that from the standpoint of the teacher and the school in general, the solution of the problem of transfer of training is *to train for transfer.*

So conclusive and convincing indeed are the results of the studies just mentioned especially with reference to the effect of method of controlling the experimental conditions upon the amount and certainty of transfer, that the second significant advance in our thinking on transfer of training lies in a fundamental change in Thorndike's own position, as shown in the following quotation:

> Studies of the transfer of training also have shown that the methods used in guiding the pupils' learning activities have marked effect upon the degree of transfer. The more clearly the crucial elements or fact or *principle* in a situation is brought to the pupil's attention the more readily the same element or fact or *principle* may be identified in another situation. . . . If a child observes, *despite many differences in details* in a new mechanical puzzle, that the vital *principle* is the same as in puzzles previously solved, the solution is more likely to be achieved than when the *common principle* is not identified.[9]

[7] McKinney, F., "Identical Sensory Elements versus Functional Equivalents in Visual Transfer Reactions," *Journal of Genetic Psychology*, 41:483–489, 1932. (*Psychological Abstracts*, 1933, No. 2303)

[8] Cox, J. W., "Some Experiments on Formal Training in the Acquisition of Skill," *British Journal of Psychology*, 24:67–87, Part I, 1933.

Laycock, S. R., *Adaptability to New Situations*, Warwick and York, 1929, 170 p.

Margineanu, N. *Psihologia Invatarii* (Psychology of Learning) Cluj, Roumania: Inst. de Psihol., Univ. Cluj, 1931, 166 p. (Summarized in *Psychological Abstracts*, 1934, No. 2493)

Olander, H. T., "Transfer of Learning in Simple Addition and Subtraction," *Elementary School Journal*, 31:358–69; 427–37, 1931.

Overman, J. R., *An Experimental Study of Certain Factors Affecting Transfer of Training in Arithmetic*, Warwick and York, 1931, 235 p.

Salisbury, R., "Study of the Transfer of Training in Logical Organization," *Journal of Educational Resources*, 28:241–254, 1934.

Zyve, Claire, "Experiments in the Teaching of Integrity," *Teachers College Record*, 32:359–374, 1931.

For other studies made from 1890–1927 bearing on this matter, see the present writer's *The Theory of Identical Elements*, Chapters VI and VII, p. 77–142.

[9] Thorndike, E. L. and Gates, A. I., *Elementary Principles of Education*, Macmillan, 1929, p. 104. (Italics are mine.)

Note the terms "principle," "despite many differences in details," and the proviso with reference to the effect of methods of teaching upon the "degree of transfer." The quotation sounds very much like one from Judd, so much so in fact that several writers have made a claim to the effect that Thorndike and Judd are in fundamental agreement on this issue. Says Carroll: "The conclusion to which the writer has come is that Judd and Thorndike are fundamentally one with respect to transfer, though each is emphasizing an opposite extreme."[10] Sandiford claims that "Judd's generalization of experience . . . resolves itself into nothing more nor less than the formation of specific . . . habits having applicability to situations other than those in which they were learned."[11] And Douglass, summing up his views on transfer, says, "In the minds of many psychologists a theory of transfer based upon the process of generalization is not opposed to one which conceives of transfer as occurring through identical elements. On the contrary, when sanely interpreted, the two theories are useful supplements to each other."[12] We need not be concerned here whether or not Judd and Thorndike are in agreement concerning the meaning and nature of generalization (this point is discussed briefly in the footnote at the bottom of the page[13]) suffice it to point out that if the claim is true the change must be in Thorndike and not in Judd. This reminds us of the reply made by Judd to a question raised by a student in his class, after Judd commented on the theory of *identi-*

[10] Carroll, H. A., *Generalization of Bright and Dull Children*, Teachers College Contributions to Education No. 439, 1930, p. 4.

[11] Sandiford, P., *Educational Psychology*, Longmans, Green and Co., 1928, p. 298.

[12] Douglass, A. A., *Secondary Education*, Houghton Mifflin, 1927, p. 352.

[13] The difference between Thorndike and Judd is this: To Thorndike the identical elements are the *cause*, whereas to Judd they are the *effect* of transfer. When two situations are identical the problem of transfer disappears, and as Judd points out the *process of discovering* the identical elements by *generalization and application* is what constitutes transfer of training. The only entity that is identical in both situations before transfer takes place is the individual himself. Thorndike maintains that the identical elements are inherent in nature *awaiting notice*, whereas Judd holds that they are to be *discovered* in much the same way that a scientist *discovers* scientific laws and principles. If Thorndike is right then all generalizations should have been made at the beginning of time except those that arise as a result of natural evolution. In final analysis, Thorndike holds that the *identical elements* are *logical* in nature, whereas Judd maintains that they are *psychological*; in the former transfer takes place *automatically* if it takes place at all, whereas to the latter, transfer is very largely *consciously* and *deliberately* worked for.

cal elements as to whether or not he and Thorndike are not really in agreement. Like a flash of lightning Judd said: "Maybe so, and it pleases me immensely to learn from you that New York is coming closer to Chicago."

A third, and perhaps the most important development in the last seven years in our thinking about transfer of training, is the growing body of factual evidence, both positive and negative, from animal learning especially with reference to the "mechanisms of intelligence." In an interview with Lashley, whose monograph on *Brain Mechanisms and Intelligence* is epoch-making so far as it relates to the problem of transfer, we were told in no uncertain terms: (1) First, that the theory of *identical elements* finds no support from either neurology or physiological psychology. (2) Second, if there is anything in common between two situations in which transfer takes place, it does not consist of the elements of the situations, but rather in the *relationships among the elements which are perceived by some mysterious process of insight.* And (3) finally, it appears therefore, that far from being a dead issue, as most people at present are inclined to believe, *the theory of formal discipline is still an open question.* To quote from Lashley's monograph:

> There is no evidence to support this belief in identity of nervous elements. On the contrary, it is very doubtful if the same neurones or synapses are involved even in two similar reactions to the same stimulus. Our data seem to prove that the structural elements are relatively unimportant for integration and that the common elements must be some sort of dynamic patterns, determined by the relations or ratios among the parts of the system and not by the specific neurones activated. If this be true, we cannot, on the basis of our present knowledge of the nervous system, set any limit to the kinds or amount of transfer possible or to the sort of relations which may be directly recognized . . . The rejection of doctrines of formal discipline seems to have been based far more upon such reasoning (refers to the mechanistic explanation of transfer) than upon any convincing experimental evidence.[14]

[14] Lashley, K. S., *Brain Mechanisms and Intelligence,* University of Chicago Press, 1929, p. 172–173.

As a matter of fact, as shown by an analysis made in 1927, (*The Theory of Identical Elements,* Chapters II–III, p. 9–35) Thorndike's own experiments do not support the theory of *identical elements.* It must be admitted also that the theory of *identical elements* was not an outcome of the experiments which are regarded as the bases of the theory, but that the experiments were the outcome of the theory which is inherent in the S-R bond hypothesis. In this sense Thorndike experimented in order to *prove* rather than to *test* his hypothesis. This is not saying that he was wrong on this account, except that the experiments are usually regarded as *scientific*

This position of Lashley finds support in many careful laboratory studies of animal learning some of which bear directly on the problem of transfer of training. While the results of these studies are not nearly so conclusive as those obtained by Lashley, nevertheless they seem to support the thesis that even as low a level as the fish, perceptions of relationships rather than of elements explain the phenomenon of transfer. Ho, for instance, found that the amount of transfer between two similar motor habits in rats depends upon the *degree of integration*[15] of the habits involved, whereas Jackson's study revealed that in learning a maze the responses that are transferred in albino rats are of the nature of *an attitude of a general motor set* rather than of specific overt responses.[16] In an extensive investigation covering two years with more than 300 albino rats, Alm found that the elements transferred were *response patterns* rather than specific responses.[17] Other studies by Gulliksen,[18] Hadley,[19] McKinney,[20] and a few others, seem to confirm the results indicated above. The net conclusion to be drawn from the foregoing facts seems to be unequivocal: If animals do not behave as mechanically as the theory of *identical elements* requires, we can infer without reservation that man, who is supposed to be more intelligent than fish, rats or monkeys, may be assumed to act even less mechanically.

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when in fact they are *pseudo-scientific*. All studies in education insofar as they make presuppositions as to *standards of value* to be attained, and they all make such assumptions if they are educational at all, are pseudo-scientific, whether or not they are so recognized. However, as will be shown later, the very pseudo-scientific nature of educational investigations is our only salvation from ruin. In fact, it is this that can and must humanize education. (It should be clear from this that we use the term pseudo-scientific in this article without the element of mockery that is usually attached to it.)

[15] Ho, Y. H., "Transfer and the Degree of Integration," *Journal of Comparative Psychology*, 8:87–99, 1928.

[16] Jackson, T. A., "General Factors in Transfer of Training in the White Rat," *Genetic Psychology Monograph*, 11, No. 1, 1932, 59 p.

[17] Alm, O. W., "The Effect of Habit Interference upon Permanence in Maze Learning," *Genitic Psychology Monograph*, 1930, 10, 379–526.

[18] Gulliksen, H., "Studies of Transfer of Response: I. Relative versus Absolute Factors in the Discrimination of Size by the White Rat," *Journal of Genetic Psychology*, 40:37–51, 1932.

[19] Hadley, C. V. D., "Transfer Experiments with Guinea Pigs," *British Journal of Psychology*, 18:189–224, 1927.

[20] McKinney, F., "Identical Sensory Elements versus Functional Equivalents in Visual Transfer Reactions," *Journal of Genetic Psychology*, 41:483–89, 1932.

The present tendency in the various related sciences to emphasize synthesis more than the traditional notion of analysis lends support to the point of view that has just been indicated. In physiology, for instance, Sherrington's hypothesis of the *integrative action of the nervous system* seems to be confirmed by experimental evidence especially from the studies of Herrick and Child. The findings of the *Gestalt* school seem also to re-enforce the organismic as compared to the mechanistic conception of behavior. Thorndike himself a prominent sponsor of mechanistic psychology has given up his *law of exercise* in its original form, which is the very heart of the S-R bond theory of learning. To the connectionist the establishment of a connection between the stimulus and the response takes place mainly through the reduction of the resistance of the synapse by exercise. Thorndike's hypothesis of satisfaction and readiness without or in spite of repetition is an indication of a belief in some factor other than specific connectionism to condition learning and transfer of training. It is difficult, of course, to conceive how mere satisfaction resulting from a satisfactory response to a confronting situation "stamps in" the process and thereby makes the reaction automatic without some amount of repetition, or how dissatisfaction prevents learning in spite of several repetitions. Nevertheless, it is in support of the organismic concept of behavior at least negatively in the sense that learning can no longer be regarded as a matter of repetition of reactions. Even in physics the emphasis on mechanism is being overshadowed by the newer concept of relativity which, in the main, supports the integrative and organismic hypotheses. The emphasis in the mathematical field on functional relations of variables has gone far ahead in making this theory articulate with progress in mathematical knowledge. What seems to be the trouble now in mathematics, and in other fields too for that matter, is that the teaching of functional relations does not function except in terms of verbalization and parrot-like reproduction of meaningless identities.

A fourth development in advancing the frontier of thinking on transfer of training is the serious attempt on the part of the subject matter specialists to experiment on various methods to bring about transfer in their subjects. It will be noted in Table III below that the number of *classroom investigations* increased from 23 to 45 in 1927–1935, or almost double the number for 1890–1927,

whereas the corresponding figures for *laboratory experiments* show practically no change.

TABLE III

Number of Classroom and Laboratory Studies for 1890–1927 and 1927–1935 Compared

Kind of Investigation	1890–1927	1927–1935
Classroom	23	45
Laboratory	56	51

While it is true that the evidence is positive in the majority of the studies, nevertheless the fact remains that the amount of transfer from the various subjects is very much smaller than has been generally believed. This fact has led many an extremist to jump at the startling conclusion that the various subjects of the curriculum are equal in educational value. Such a position is not by any means new. The famous Committee of Ten and the Committee on College Entrance Requirements based their recommendation for the adoption of the well-known *principle of equilitarianism* with respect to secondary school subjects on the assumption that *all subjects competently taught for the same length of time have the same educational value.*[21] And since no standard of competency was defined by these committees or by any other authority, the term *competently taught* could only be taken to mean, *as ordinarily taught,* and that therefore "all that remained of the principle was that a unit or point or credit of one subject was as good as another."[22] This point of view seems to have received its "final scientific sanction" in the so-called "classic study of mental discipline in high school" by Thorndike.[23]

The inference drawn from the facts disclosed by these studies is that a study or subject "is not valuable in itself because it develops ability to transfer, but that abler pupils, taking these subjects, cause those subjects to have great transfer value. In other words, to quote Thorndike exactly, 'Whatever studies they (the

[21] Kandell, I. L., *The Dilemma of Democracy*, Harvard University Press, 1934, p. 28.

[22] Ibid., p. 28

[23] Thorndike, E. L. "Mental Discipline in High School Studies," *Journal of Educational Psychology*, 15:1–22; 83–98, 1924.

Broyler, C. R., Thorndike, E. L. and Woodward, E. A., "A Second Study of Mental Discipline in High School Studies," *Journal of Educational Psychology*, 18: 377–405, 1927.

bright) take will seem to produce large gains in intellect,' because of the fact that 'those who have the most to begin with gain the most during the year' irrespective of subject material."[24] As Kandell humorously points out, "it is now possible for administrators to guarantee the greatest happiness of the greatest number of pupils on the principle that from the point of view of satisfaction 'pushpin,' to use Benthan's phrase, 'is as good as poetry,'" and it may likewise be added that from the standpoint of mental discipline, bookkeeping is not only equal to, but it actually possesses greater training value than Latin, and probably geometry and logic too![25]

It is perfectly clear that if we grant the premises upon which the inference indicated above is based, we have to accept the conclusion. We have only therefore to inquire further whether or not the various subjects *as ordinarily taught* are *competently taught*. Fortunately, we have an indisputable evidence from more than forty studies to the effect that the objectives of the different subjects in terms of knowledge and skills, are far from having been achieved in the schools.[26] That is to say, the pupils pass algebra without knowing how to solve problems and exercises in algebra, or are promoted in physics without knowing how to apply the simple formulas learned in the solution of physics problems. In plain everyday English, there can be no transfer unless there is something to transfer. Of course, as will be shown later, there are other reasons for lack of transfer, but it goes without saying that in order to have fried fish for dinner one must first have fish to fry. If the students do not know physics after studying it for a year, does it not seem absurd to expect them to apply the principles of physics to the practical affairs of life? If the pupils do not learn demonstrative geometry in class, does it not seem unreasonable to rely on them to deal logically with assumptions and proofs in other fields than demonstrative geometry? If students of Latin do not know Latin after studying it for three years, have we any reason to suppose that they should be any better able to deal with anything which

[24] Carroll, H. A., op. cit., p. 8.

[25] Kandell, I. L., op. cit., p. 28 and 31.

[26] Brownell, W. A., et al., "Types, Characteristics, and Problems of Learning," *Review of Educational Research*, Vol. III, No. 4, p. 289–94.

Briggs, T. H., *The Great Investment*, Harvard University Press, 1930, p. 124f.

Latin is expected to promote than those who have had no Latin at all?

The conclusion at this point seems inevitable. Since the various subjects *as ordinarily taught* are *not competently taught*, the *principle of equilitarianism* of school subjects as explained above cannot be accepted as valid. This opens up the question of transfer once more. While it is true that the amount of transfer from the various school subjects is, on the average, small we have indisputable evidence to show that it can be increased enormously. An analysis of the results of the nearly two hundred studies indicates that the amount of transfer varies from zero or even negative quantity to almost perfect. The difference as far as we can determine seems to lie, first, in the amount that is available for transfer, and, second, in the degree to which conditions are made favorable to transfer. The inference that may be drawn from this is simple indeed, namely, to improve instruction so that transfer will take place. In particular, if one wishes to improve mathematics instruction so that it will transfer, one must teach it better. This is so much like a truism that it seems ridiculous even to state it. The case is analogous to what Gray discovered after making a five-year investigation in the field of teaching reading, namely, that pupils can learn to read well if they are taught how.[27] Well, why not?

III. Extending the "Frontier" One More Step

The discussion up to this point may be briefly summarized as follows: (1) The fact of transfer can no longer be doubted, but it is not an automatic process like Upton Sinclair's EPIC or the Tugwellian formula of bringing back prosperity. It is something to be worked for directly. This does not mean training in specific responses to specific situations, but rather the development of the ability to deal with situations that require reconstruction and reinterpretation. (2) The facts from the structure and function of the nervous system seem to warrant the inference (a) that the nerve elements do not act singly but as a whole and in coordination, and (b) in function the nervous system is flexible and adaptive rather than rigid and

[27] Gray, W. S. and Whipple, G., *Improving Instruction in Reading*, University of Chicago Press, 1933, 226 p. In reviewing this monograph in the March, 1934 issue of *Educational Administration and Supervision*, A. S. Edwards says in part: "It appears that all schools that seriously tried to improve made distinct progress in increasing the achievement of pupils in reading." Why shouldn't they?

mechanical. This gives us a clue to the problem of transfer of training. Nature gives us a choice between flexibility on one hand, and fixity on the other. In fact, the irony of the situation is that the nervous system is so flexible that it can be made rigid and fixed if we control the conditions appropriately. The implication of this upon behavior is obvious enough. We can train the individual in such a way that he behaves like an automaton, or we can educate him so that he can act intelligently. In terms of our problem, we have a choice between little or no transfer at all and transfer in any amount.

This is both a challenge to our efforts and an encouragement for us in these wearisome days of trial and error education. We must no longer, Micawberlike, be indifferent to the phenomenon of transfer by waiting for something to turn up; nor can we regard transfer as an inevitable event like the birth and death of David Copperfield. But rather we should take the position that transfer takes place in any form and amount according as we give it a chance to take place. In other words, to add one more figure from Dickens' novel, transfer is like Barkis in the novelist's characterization of him,—"Barkis is willin' ". If we are as anxious with reference to transfer as Peggoty is to Barkis, we can have it for the asking.

The next question naturally is, how can we get it? To answer this question requires answering another question which is not so simply stated much less easily answered. Up to this time, transfer of training has been regarded as a purely scientific problem, and more specifically, a psychological problem. As one writer remarked the democratic ideal or any social or political theory has nothing to do with it, meaning, the "scientist's unprejudiced approach to a problem." "Each (science and social philosophy) has its place, and for the scientific worker (or anyone else) to mix them is to arrive at muddled conclusions."[28] This may be so, but the question we are raising is not whether the ideal of democracy *has* anything to do with the problem of transfer of training; but whether such an ideal *should have all* there is to do with it or with any scientific problem whatever. As stated at the outset, we are convinced that the problem of transfer of training is primarily, for us, an educational, and only secondarily and incidentally, a scientific problem. To be sure it may be viewed scientifically by the psychologist *as*

[28] Carroll, H. A. (Book Review), *Journal of Educational Psychology*, 20: 636–37, 1929.

a scientist, but as educators we should be permitted to look at it from another angle, loading the dice with as much weight as we care to place upon the democratic ideal or any other social value that we wish to achieve.

It is our belief that the time is propitious to advance the frontier of thought on this problem one step furthrer. Instead of asking as we do now, "Is transfer possible, how does it take place, and in what amount?"—let the psychologist *per se* ask and answer these questions to his "unprejudiced" satisfaction,—we should ask: "Do we *want* transfer, and if so, what, in terms of ideals, attitudes, beliefs and habits, do we *want* transferred; and what provision *should* we make in method of learning and teaching, administration and the like, in order to bring about transfer in the form and amount that we *desire?* Please notice the change from *is* or *is not* to *should* or *should not*. The problem becomes essentially a technological problem instead of a problem that is purely scientific in character as it is ordinarily regarded by most people. It is not a matter of the discovery of identical elements by analysis of varying concomitants, like the biologist discovering the principle of evolution or the physicist discovering the law of gravitation. It is rather a problem of creation, construction, building up of attitudes, ideals and beliefs in the light of a desired social value. It is more of a problem of "human engineering," to borrow a technological phrase, than that of discovering the nature of an electron. Instead of a Davenport, we should have a Luther Burbank; in place of a Faraday we should have a Thomas Edison. Not that Davenports and Faradays are not important, but *as educators*, our job is not to discover laws, but to make men. Edison created the incandescent lamp and Luther Burbank created a new variety of peas after a prescription from a manufacturer. In like manner, let us create attitudes, ideals, ability to make inferences and to think logically, and even an attitude of "unprejudiced approach to a problem." These are not processes or entities inherent in nature awaiting notice from us, but creations or inventions. We build character, —we do not find it. The child learns to be honest, not by discovering it but by reacting to situations and the situations reacting back in a way that would result in the making over of both the situation and the response. We do not discover that honesty is the best policy, but we make it so that it is the best policy. A pupil learns or should learn his mathematics not by discovering the

answers or even by proving them, but by making his calculations in terms of the requirements of the problem, by analyzing the parts and putting them together again in different patterns in order to arrive at a satisfactory solution. The child does not just discover that 22+0 makes 22. He "adds" to it his previous experience with 2+0 and in so doing he transforms it into something that he can deal with satisfactorily. It is not just a matter of reading 2+0 in 22+0 although that may well enter into the situation, but rather the realization of the principle that a naught added to something, whether it be a number or a pound of flesh, does not change its value. Without this principle, which is a meaning and a creation rather than an entity and an abstraction, the pupil may well continue dealing with zero combinations without noticing the "identical elements".

Let us apply this hypothesis of construction to the teaching situation. If the teacher simply drills the pupils in 2+0, 0+2 and the like so that they will finally react by saying "2" in each case, what would be their reaction to 22+0? They simply see it as another combination whose answer is to be discovered, and so they learn it as before by repetition. But suppose instead that the teacher points out the meaning of 2+0 as indicated in the preceding paragraph, what a change in their perception of 22+0 and 0+22 or even 23478+0! We often say that to act intelligently is "to put 2 and 2 together," not to take them apart. One way to teach number combinations is to teach them all directly by drill, and in this case transfer is not only unnecessary but impossible. You learn what you learn. Another way is to teach the meaning of combinations, such as 2+0, which means as indicated above, nothing added to a number does not increase the value of the number. What a rich concept for listeners to radio advertising if generalized even further! In fact, the ability to transfer can be generalized too so that it can be used to deal with countless fields of life interests. This is really what we mean by learning in its broadest sense. It is acting intelligently.

If we take the higher processes as for instance, logical thinking, the phenomenon of construction as a process of learning and of transfer becomes even more apparent. Thinking is no piecemeal activity that can be learned by memorizing facts or by following the rules of logic in routine fashion, or even by dissecting the whole into its constituent elements, important though these processes

undoubtedly are. It is rather the putting together of the facts, details, data and the like in relation in order to solve a problem. Analysis enters in, to be sure, but synthesis is even more vital. As a matter of fact, analysis may be viewed as a type of synthesis in the sense that the individual in making an analysis of a situation, does not really break up the problem into physical parts, but that he looks at it from different angles or points of view. Viewed in this light, transfer is a power rather than an entity or even a method of a mechanical sort.

This should give us another meaning for the term generalization which we introduced sometime back. As indicated early in this article, the bulk of evidence is in favor of Judd's theory of *generalization*. But notice that generalization can be as mechanical as transfer through *identical elements*. Many of the experiments that claim to be an application of the hypothesis of generalization resulted in very little amount of transfer because the pupils memorized the rules or followed them mechanically. This is the danger of regarding generalization simply as a matter of discovering relations and of stating them in terms of a principle which may be just verbal. The application of the principle may be as mechanical. As a matter of fact, the pupil will understand that if the law or principle is scientific at all it must be capable of mechanical application. What really matters is not whether the pupil generalizes and makes the application, but whether his generalization and application meet the requirements of the situation. It is true of course, that there are scientific generalizations over which we have no control, like the law of gravitation. But unfortunately, there are also countless generalizations that cannot be regarded as final, fixed or immutable. In the realm of ideals, standards, relations, generalizations vary from country to country, and from time to time. Is it possible to say in this case that the child discovers the principles like the scientist discovers the weight of the electron? In fact, the problem in social relations is not so much the ability to generalize and apply, but to deal with changing ideals and standards, which means the ability and willingness to change the generalizations made previously in accord with the needs of a changing social scene. This ability to deal with changing principles or generalizations Judd's theory does not seem to provide for, much less does Thorndike's theory of identical elements.

What is the bearing of this point of view upon the work of the

teacher? What is the next step with reference to the problem of transfer of training? The first problem we need not elaborate upon for lack of space suffice it to indicate briefly: first, the teacher should know what it is that she wants the children to transfer to other fields, second, she must learn by experience or experiment how to teach for transfer, and third, to go ahead and do it. As to the next step in experimentation, the same suggestions will apply. After the fundamental objectives are decided upon, and these will naturally include what, in terms of attitudes, ideals or basic beliefs and habits, are desired to be *transferred* from the school to the social situation, research and experimentation will proceed in the determination of the best means of attaining them. This approach is entirely different from present methods wherein the research worker in the guise of being objective and scientific looks at his problems in an unprejudiced manner, that is, without regard to social values to be attained. This sounds like advocating the practice of what psychologists call *rationalization*, and so it is. All education is rationalization in this sense, and likewise all educational research is pseudo-scientific. Why not? It is better to be right than scientific.[29] It is inescapable besides. As Rugg points out in a recent article, "Students of quantitative methods of inquiry must be reminded that the theory held by the investigator (whether they are aware of it or not) determines the nature of the problem which he chooses to study, the organization of the experiment, the choice of procedures, the arrangement of the experimental scene, the methods by which changes are recorded and results are measured, and the interpretation of the data."[30] The experiments in transfer of training illustrate this very fact. As pointed out early in this paper, the findings of two or more investigators vary according to the method of procedure, the control of factors, the kind of training that the subjects undergo, and various other conditions that are involved in the whole complex process. Thorndike did not get

[29] There is this difference, however. If educators, including educational research workers, recognize this fact, they will avoid scientific pretensions and consequently become more critical of their assumptions, findings and interpretations. Furthermore, educational research workers will be relieved from the false notion that the only way to the truth is via the statistical and experimental method. When so broadly conceived and interpreted education becomes an *art* and a *technology*.

[30] Rugg, H. "After Three Decades of Scientific Method in Education," *Teachers College Record*, 36: 111–122, November, 1934.

transfer from his experiments because the training provided made it difficult or impossible for transfer to take place. On the other hand, other investigators obtained considerable transfer because they provided conditions that are favorable to transfer. Some of these conditions are: "conscious formulation of general principle and application to varying situations," "discussion and analysis of problems with reference to a point of view," "emphasis upon meanings and concepts and reconstruction of experience," better organization of subjects around social issues that are vital to the child, and the like.[31]

It remains to add that the kind of training that will transfer to the social situation is not obtained, except rarely, by even the most effective study of formal subjects. We cannot ignore or even be indifferent to the social scene and at the same time expect the child to be able to deal with it satisfactorily through the medium of his training in school. It is possible to so train the child that he can see the meaning of 2+0 in the most complicated mathematical problem without being able in the least to see the corresponding social fact that we cannot get anything for nothing, radio advertisers to the contrary nothwithstanding. To put it differently, the various subjects of the curriculum cannot be expected to result in automatic transfer to the social situation that confronts the child unless, by proper instruction and organization of these subjects, they can be made "a way of life" and be so used by the child himself. This is what we mean by "humanizing education" in the concrete.

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[31] For detailed suggestions from experimental studies see Orata, P. T., *The Theory of Identical Elements*, Chapters VII–IX for 1890–1927, and the following for 1927–1935: Bruce, Cox, Dorsey, Laycock, Olander, Overman, Salisbury and Zyve (Part I); Archer, Betz, Burt, Cavenaugh, Dunlap, Eaton, Whipple, and the series under "Teaching Scientific Method" (Part II)—Consult *Bibliography*.

[1] With very few exceptions this bibliography includes only the references from 1927–1935. For additional references from 1890–1927 see Orata, P. T., *The Theory of Identical Elements*.

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Summer Meeting of the National Council of Teachers of Mathematics

The National Council of Teachers of Mathematics will hold a summer meeting this year in connection with the meeting of the National Education Association at Denver, Colorado from June 29th to July 1st. The Argonaut Hotel will be headquarters. Write direct to the hotel for reservations.

There will be a formal program on Saturday afternoon June 29th and a banquet at night followed by an address. On Sunday the Council members will be the guests of the local committee which is planning some sort of a mountain trip. There will be a breakfast on Monday morning followed by a round table discussion. On Monday afternoon there will be a joint session of the Council with the department of Secondary Education the general topic for discussion being "Contributions of the Teaching of High School Mathematics to the Solution of Youth Problems of Today."

One session of the Council meetings will be devoted to the junior high school and one to the senior high school.

Attention Teachers!

Are you leaving your present position? A teacher of mathematics and physics looking for a position will pay 4% of his first year's earnings resulting from information received about such an opening.—Address: E. Nelson, 3109 Clarence Avenue, Berwyn, Ill.

Why Teach Geometry?

By VERA SANFORD
State Normal School, Oneonta, New York

Some years ago, a visitor questioned a class in plane geometry asking what benefit they had received or expected to receive from their study. The pupils gave the customary answers: the uses of geometry in the arts and in science, contact with an ancient body of knowledge, and a possible vague benefit to their minds. The visitor parried each reply with the proper time-honored criticism and then one student blurted out "I like geometry because it gives me mental satisfaction."

The writer is in an analogous position. The reasons for teaching geometry have been given by people who are far more able to treat the subject, but perhaps there is a place for the credo of a teacher whose first interest in mathematics can be traced to the study of plane geometry and whose chief reason for that interest is mental satisfaction.

To begin with, let us consider geometry from the point of view of the uses which we make of it, and, because labels are sometimes convenient, let us classify these uses as vocational, informational, and abstract:—geometry for its applications, geometry for the pleasure it gives us in other connections, and geometry for the pleasure it gives us for its own sake.

VOCATIONAL GEOMETRY

The applications of geometry are varied, but it is a question how many are of essential importance to every individual. We must admit also that the application of a geometric principle is often the result of following a rule rather than the outgrowth of a person's knowledge of geometry. A carpenter who is cutting rafters for a building in which the roof terminates with the comb with no overhang, virtually uses the concept of similar triangles and the theorem that the acute angles of a right triangle are complementary, without realizing the fact that he is using geometry at all. To him the process is a building rule. We might add many other examples of the unconscious applications of geometric principles.

Other applications of geometry are of such specialized fields as to seem totally fictitious to the majority of the people who hear of them. The establishing of the position of a ship by the radio direction finder is a case in point.

In collecting the applications of vocational geometry then, we have a full gamut of cases from the ones in which geometry is used without a realization of the fact to those in which the application although real to a few specialists is purely vicarious experience to many.

We have a tendency also to elaborate an instance of the real application of a theorem to cases in which the application is manufactured to suit the principles involved. An illustration of this occurs in the problem of locating the center of a circle when only a portion of its circumference is given. This had a real application to an archeologist who was anxious to reconstruct a chariot wheel from a small part of the rim of the original wheel. We find in texts in geometry that the theorem is given applications ranging from the chariot wheel to a cart wheel and a mill wheel. It is the writer's opinion that the current interest in archeology will carry the application without transferring it to carts or mills. Yet the study of the texts seems to indicate that the authors think the problem gains in interest in being transplanted into the twentieth century.

It is a platitude also to remind the reader that one function of school work is to lay such preparation for the applications of school work as will enable the student to make use of his knowledge in connections which his teachers cannot foresee. The case of the radio direction finder illustrates the point. Accordingly, it is probably wise to suggest to the pupil uses of geometry which are outside of his immediate experience with the idea that the study of these applications may make him more alert to see and appreciate other uses as these occur.

As a tentative list of the principles and concepts of geometry which may be justified on the basis of their real applications, let us say: *Area and Volume Formulas, Theorems Regarding Similar Figures, Angle Sum of a Triangle, and the Pythagorean Theorem.* This is a short list. The greater part, if not all of it, is established in the junior high school by intuitive and experimental methods. This fact would lead some critics to suggest that all the geometry that is needed should be given in those years, and certain of the iconoclasts would have us spend our time in applying the theorems to

special cases rather than putting a part of it into the derivation of the theorems. This brings us to a question of method. In some cases, it seems that the opinion of these people is being followed. In these instances, however, the pupils are missing one of the most interesting phases of the work,—the actual experience of the deriving of scientific laws by controlled experiment.

Caution must be exercised. There are cases in which it is surely wiser to check on theorems whose validity is assumed to be true rather than to attempt to derive them *de novo*. In finding the formula for the area of a circle, a class is likely to be completely lost if the work is presented as finding the number of squares on cross-section paper that are included within the circumference. Their attention is concentrated on the little squares and they lose sight of the main purpose. Certain of the authors present this problem as one of checking over some other person's work. The pupil repeats the experiment to be certain that the other work is correct—a much easier process. He then has the time within a class period to have practice in applying the formula $A = \pi r^2$ to a number of different cases.

In other instances, however, we have small right to deprive the student of the joy of finding things out for himself, even though it occasionally leads to such erroneous ideas as that the volume of a cylinder may not be really three times that of a cone having the some base and height as the experiment seems to show, but instead as π has a great deal to do with circles, perhaps the volume is really 3 1/7 times as great.

There is a double task in the teaching of vocational geometry,—the applications which we know the student must make and those unknown ones for which our only preparation can be the increasing of the student's ability to apply his knowledge in new and unexpected ways.

Informational Geometry

Informational geometry begins when we first experiment with ideas of shape, size, and position, and our knowledge of it should continue to grow as our interests widen even into adult life. The child in an old-fashioned kindergarten who talked of a "triangular prisoner," would seem pedantic in a modern school, but kindergarten children have a surprising knowledge of simple geometric terms. At the other end of the scale, it is unusual to find adults

who see why the apparently curved route of a trans-Atlantic airplane flight may actually be the shortest path between the terminal points.

A list of things that are essential in our equipment of informational geometry is as follows: *Names of geometric figures and solids, —angle, triangle, quadrilateral, rectangle, parallelogram, polygon, circle, arc, chord, rectangular solid, cylinder, cone, sphere, prism, pyramid. Concepts of congruence, similarity, parallelism, perpendicularity, symmetry, area, and volume.*

It will be realized that the study of informal geometry which begins when the child learns to talk, continues into his adult life and naturally a person's ideas undergo a clarifying process as his experience widens. A young child may call a certain figure a "round circle." A junior high school pupil may instead recognize it as a figure of such properties that it is useful for building wheels so that vehicles will move smoothly, useful in making coins so that they will stack readily and will not wear holes in our pockets as they would if they had corners. The student of demonstrative geometry will see in a wheel an application of the idea that a circle is the locus of a point whose distance from a fixed point is a constant. The machinist is interested in circles for their uses as gear wheels mounted centrally and off center. You and I as teachers of mathematics may have added to these other bits of information about circular points at infinity. We see π as a strange interloper in the number scale, a concept whose significance has not been grasped by the circle squarers. We may study the idea of continuity as Professor David Eugene Smith has done in his motion picture "The Play of the Imagination in Geometry."

A little reflection shows that our knowledge of informational geometry is gained partly by intuition and experiment, and partly through demonstration just as our ideas of informational arithmetic are enlarged by the manipulation of arithmetic materials.

Abstract Geometry

It will be granted that some applications of geometry and certain items of informational geometry should be included in the curriculum, but what about the abstract side of the subject? In discussing the meaning of education, J. Herbert Blackhurst says, "The activities of man may be classified in four groups of which the economic, the civic-social, and the educational are means only,

and the cultural activities are the end, largely justifying the others."*

Cultural geometry may seem a misnomer and yet one label will do as well as another. What are the distinctive contributions of geometry to the cultural development of the individual? What does geometry give that is not better handled by the physical and social sciences or by the plastic or graphic arts?

Let us take as a premise that a cultured person has the ability to study a topic with an open mind; to weigh each argument carefully and critically; to suspend judgment until actually convinced; to distinguish between definitions which are merely tags to help us think and postulates which are statements true because we say so; to be aware of the existence of different types of argument or proof and to know the precautions needful in using them; to have that flexibility of mind that enables one to see when a concept needs to be extended and revised and when old convictions must be replaced by new ones. In brief, to think objectively and precisely and to judge the thinking of others with discrimination and sympathy. The truly cultured person should be able to marshal these abilities in any of his activities. He should be as critically thoughtful of his inherited religious beliefs or political biases as he is regarding new music, new architecture, current science, or changing economic ideas. If we believe that training in critical thinking comes through conscious practice in critical thinking, then we must scan the curriculum to find something to think about. It would be well to begin with some topic in which we can work without the handicap of the ideas of our grandfathers. The guardsman in *Iolanthe* put it cleverly when he sang,

> Every boy and every gal that's born into this world alive
> Is either a little Liberal, or else a little Conserv*ative*.

Politics would be a poor subject for one's conscious beginnings of reflective thinking. The handicap is too great. The same applies to religion.

We have less prejudice with regard to the social sciences, but here the so-called facts have a disconcerting way of blocking our best arguments. We build up a structure of logically reinforced reasoning and we find that it is built on the quicksand of human relations and a slight disturbance wrecks our theory. We may put

* *Introducing Education*. Longmans, 1932, p. 57.

our best energy into a problem and overlook some important consideration. Our ancestors proposed closing the United States Patent Office because all possible inventions had been made. This was in the latter part of the eighteenth century. Their arguments seemed conclusive. The complex nature of society necessitates our looking elsewhere for the prototype of logical thinking. But, once equipped with the ability to go adventuring with one's mind, the social studies offer a challenge that is irresistable. Meantime, they remain in the informational rather than the other class.

The physical sciences are relatively less complex but here again we are face to face with the world as it seems to be and we find that our best hypotheses are subject to revision as new things are discovered. Where shall we stand with regard to Newton's corpuscular theory of light or Young's wave theory? Each used reasoning that was magnificent. Were both wrong? Was one right? Is one studying discrete phenomena and the other the statistical effect of masses of these phenomena? Even in more elementary physics things as they exist are a constant handicap and challenge to an active mind, but we can scarcely hope to include each and every factor.

On the other hand, the field of geometry offers both the fate and the freedom which the adventurer demands. He has liberty in choosing his postulates as had Euclid, Lobachevsky and Riemann. He has liberty in applying names to concepts and to enlarge these concepts as he wills. If it is convenient to extend the idea of an angle to straight angles, reflex angles, multiple and negative angles, he is at liberty to do so although his forebears were slow to see their privileges. He has no inherited predilection for an isosceles triangle or for an oblique parallelogram. He may represent these concepts with ease and with what seems to be precision, and from his diagrams he can often draw further hypotheses. He can distinguish more readily between a statement and its converse than he can in other fields. In a proof by exclusion, he can provide more surely for all emergencies and when he writes *Q.E.D.* at the end of a theorem, he has the satisfaction of feeling that it *has* been demonstrated. Geometry is a subject which provides its greatest joy when you have proved your point and have compelled your opponent to grant the cogency of your argument. Yet its liberties are liberties only within the laws which you set of yourself when you choose your postulates.

Taught from this point of view, it makes relatively little differ-

ence which of a number of sequences we follow. *Book theorems* are not objects to be memorized; they are things to be discovered by the class. They are printed out only as patterns or to facilitate future reference. A class will listen attentively to the work of one of its members knowing that any shoddy points of reasoning must be set straight before the job is accepted. We spend more of our lives judging the thinking of others than we do in pioneer thinking for ourselves.

Reasoning in geometry should be compared and contrasted with reasoning elsewhere. The ideal end product would be increased facility in reasoning and in judging reasoning in other fields. Whether we shall achieve it or not is a question, but might we not say that we are more likely to gain it through the medium of geometry than through the "content" subjects?

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THE MATHEMATICS TEACHER
525 W. 120th Street, New York, N.Y.

The 16th Annual Meeting of the National Council of Teachers of Mathematics, Atlantic City, New Jersey, February 22-23, 1935

By EDWIN W. SCHREIBER

Meeting of the Board of Directors

Including Minutes of the Adjourned Meeting at 4:00 P.M.

Hotel Chelsea, Parlor C

February 22, 1935, 11:00 A.M.

PRESENT: J. O. Hassler, Ralph Beatley, Allan R. Congdon, Edwin W. Schreiber William D. Reeve, Vera Sanford, John P. Everett, Raleigh Schorling, Martha Hildebrandt, H. C. Christofferson, Edith Woolsey; Marie Gugle, past president; Olive A. Key, representing H. C. Barber; and J. T. Johnson, representing Mrs. Elsie Parker Johson.

ABSENT: Herbert E. Slaught, Mrs. Elsie Parker Johnson, Harry C. Barber, W. S. Schlauch, William Betz.

The meeting of the board of directors was called to order by President J. O. Hassler of Norman, Oklahoma. The minutes of the previous meeting were read and after several suggested corrections were approved. The treasurer's report was presented and discussed and approved with the provision that it meet the approval of the auditor, W. S. Schlauch, who was not present at this meeting. A motion was made, seconded, and carried to establish a policy of three meetings a year; one in July with the N.E.A., one in December with the American Association for the Advancement of Science, and the annual meeting to be continued as in the past in connection with the Department of Superintendence of the N.E.A. in February. A motion was made, seconded, and carried to appoint a committee to draw up a more equitable and intelligent policy in regard to the payment of the expenses of the board of directors than the one now pursued. It was moved, seconded, and carried that the present policy of paying the expenses of directors attend-

ing the annual meeting, up to a maximum of $50 and all of the expenses of the president and secretary, be continued for this meeting.

Annual Business Meeting of the National Council 2:00 P.M.

The annual business meeting of the National Council was called to order by President Hassler. A motion was made and carried that the minutes of the Cleveland meeting be approved as published in the May 1934 issue of the *Mathematics Teacher*. The treasurer then made a brief report of the finances of the National Council which report had been approved by the board of directors. Professor Raleigh Schorling of the University of Michigan and Chairman of the Committee on Individual Differences made a brief report as follows:

1. The work of the Committee has been limited by the disappearance of research funds from the budgets of public schools and universities. Moreover, most of the members of our committee on Individual Differences have had marked increases in pupil load and other duties.

2. The importance of the problem as regards the continued improvement of our institutions if not their very existence is becoming clear to a good many school people. Certain forces are quietly but surely reducing the place of mathematics in the curriculum and our failure to propose a sensible solution to this problem is a contributing cause.

3. Herewith I submit a report that was made to the North Central Association of Colleges and Secondary Schools which has for a number of years given hearty support to the work of our committee. This report supplements and checks some of the findings in reports published earlier.

4. Realizing that not much could be accomplished by the committee as a national project your chairman decided to do what he could as a state project in Michigan. Emphasis has been placed on a broad investigation designed to reveal basic facts about the dull normal pupil, and there has been an effort to summarize the procedures that are effective.

A considerable number of research problems have been undertaken in ten strategic centers of the state. Your chairman has met with these groups regularly for the organization and appraisal of these research projects. Approximately 350 principals and superintendents are undertaking the study of one or more of these

problems this year. The accumulation of these studies should be helpful in the future study of the problem.

5. Your chairman recommends that the tentative report be accepted and that the Committee be discharged.

Professor C. N. Stokes of Temple University, Philadelphia, made a brief report as Chairman of the Sub-Committee on Administrative Phases of the Problem of Individual Differences. Professor Ralph Beatley of the Graduate School of Education, Harvard University, made a brief report as Chairman of the Geometry Committee. Professor W. S. Schlauch of New York University made a brief report as Chairman of the Committee on Examinations. President J. O. Hassler reported for the Policy Committee since that committee at present has neither a chairman nor a secretary.

Director John P. Everett reported to the annual business meeting the result of the official final ballot which follows:

For Second Vice-President, 1935–37

(48) Jamison, G. H.
Kirksville, Mo.

(52) Miller, Florence Brooks
Shaker Heights, Ohio

For Member of the Board of Directors, 1935–38

(53) Hartung, M. L.
Madison, Wisconsin

(58) Smith, Rolland R.
Springfield, Massachusetts

(46) Lane, Ruth
Iowa City, Iowa

(42) Taylor, S. Helen
Urbana, Illinois

(66) Potter, Mary A.
Racine, Wisconsin

(47) Whitecraft, L. H.
Muncie, Indiana

Secretary Schreiber then declared the following duly elected. Second Vice-President, 1935–37, Florence Brooks Miller. For members of the Board of Directors, 1935–38, Mary A. Potter, Rolland R. Smith and M. L. Hartung.

Professor Schlauch reported that the work of the National Council had been favorably commented on at the Washington meeting of the N.E.A. last summer. Professor Schlauch was the official representative of the National Council at that meeting and presented a paper.

Professor W. D. Reeve reported on the Pittsburgh meeting of the National Council which was held in connection with the Winter meeting of the American Association for the Advancement of Science. This was the first time the National Council met with the A.A.A.S. and from all points of view it was a decidedly successful meeting.

A motion was made and carried to adjourn the meeting until Saturday afternoon, February 23, at 4 P.M.

Dinner for Official Delegates and Directors
Miss Martha Hildebrandt, Maywood, Illinois, Presiding

The following 41 were present at the dinner for official delegates and directors: Ruby Flannery, Ethel Grubbs, J. T. Johnson, Edwin W. Schreiber, Martha Hildebrandt, Dora Kearney, Buena C. Mathis, Agnes Herbert, Nanette Roche, Ann Flaherty, Olive Kee, Ralph Beatley, Raleigh Schorling, John Everett, L. J. Brueckner, Edith Woolsey, Allan Congdon, Harriet Bull, Mary Crofts, Mary Kenny, Theresa Podmele, Nathan Lazar, Maritta Palmer, W. D. Reeve, W. S. Schlauch, Vera Sanford, William Betz, Alice Reeve, Etta Henry, Howard Fehr, E. H. Hildebrandt, Virgil Mallory, John Stone, C. N. Shuster, Charlotte Morningstar, H. C. Christofferson, J. O. Hassler, Sara McCune, J. T. Rorer. T. Roland Humphreys, and Mary Potter. This annual event is more and more becoming an important feature of the annual meeting since it gives the National Council and its board of directors news items from the local organizations which are affiliated with the National Council.

First Program Meeting 8 P.M.

1. Address of Welcome—Dr. Frank J. McMackin, Jersey City, N. J., President of New Jersey Association of Mathematics Teachers.
2. Response—Mr. William Betz, Retiring President of the Council, Rochester, New York.
3. Address—"Transfer of Training and Educational Pseudo-Science." Dr. P. T. Orata, Ohio State University, Columbus, Ohio.
4. Address—"Methods of Teaching for the Maximum Amount of Transfer." Mr. Harold P. Fawcett, University High School, Columbus, Ohio.

Second Program Meeting 9:30 A.M.

Vice-President A. R. Congdon, presiding

1. Symposium on "Crucial Problems in the Field of Arithmetic Teaching." Directed by Mr. C. L. Thiele, Director of Exact Sciences, Detroit Public Schools.
   a. "Bases for Selecting Curricular Content Related to the Social Aspects of Arithmetic." Dr. Leon J. Brueckner, University of Minnesota.
   b. "What Research Reveals on Proper Drill Content of Elementary Arithmetic." Dr. Guy M. Wilson, Boston, University.
   c. "Growth Stages and the Curriculum." Carleton Washburne, Superintendent of Schools. Winnetka, Illinois.
   d. "Arithmetic in the Primary Grades." Saul Badanes, Principal, Public School 173, City of New York.

e. "Some Current Issues in the Teaching of Arithmetic." C. B. Upton, Teachers College, Columbia University.

f. "A Proposed National Committee on Arithmetic." Dr. R. L. Morton, College of Education, Ohio University.

Professor Buswell was not able to attend on account of conflicting engagements of which he notified the president.

2. Open Discussion.

Joint Luncheon Meeting of the New and Old Boards of Directors

PRESENT: J. O. Hassler, Ralph Beatley, Allan Congdon, Edwin Schreiber, William D. Reeve, Vera Sanford, John P. Everett, Raleigh Schorling, Martha Hildebrandt, W. S. Schlauch, William Betz, H. C. Christofferson, Edith Woolsey, Mary Potter, Rolland R. Smith, J. T. Johnson.

ABSENT: Herbert E. Slaught, Mrs. Elsie Parker Johnson, Harry C. Barber, Mrs. Florence Brooks Miller, and M. L. Hartung.

A motion was made and carried to recommend to the National Council its sponsorship of the policy that certification of teachers include definite subject-matter requirements. A resolution was made to be presented at the National Council meeting Saturday afternoon at 4 P.M. A motion was made and carried that the secretary set up the necessary machinery for carrying on an intensive publicity campaign for the National Council of Teachers of Mathematics. Professor A. R. Congdon made a brief report on the sale of yearbooks as the result of a campaign carried on by Professor Congdon, President J. O. Hassler, and Secretary Schreiber. Professor W. S. Schlauch made his report as auditor of the accounts of the treasurer and stated to the board of directors that he found the treasurer's report correct. He suggested in his report that the book values of the bonds owned by the National Council be listed as per schedule worked out on a scientific basis by Professor Schlauch. He also recommended that the auditor be a member of the Budget Committee and that the budget should be presented at each annual meeting with the budget of the previous year as a guide. President J. O. Hassler announced the membership of the Budget Committee as follows: Professor W. S. Schlauch, Dr. Vera Sanford, and Professor H. C. Christofferson. It was moved and carried that the format of the *Mathematics Teacher* be changed as recommended by Professor W. D. Reeve, the change to take place beginning with the January issue 1936.

Professor Schorling was called on to state the reason why he

wanted the Committee on Individual Differences discharged. Professor Schorling felt there was not enough support given the committee by the Council. The motion was made and carried that the committee should be continued and financed as far as possible. Professor Schorling asked for the arrangement of a conference so that those interested in the subject could discuss the matter at some length. It was moved, seconded and carried that the president appoint a Budget Committee consisting of three members, said committee to submit a prospective budget for the ensuing year.

THIRD PROGRAM MEETING 2 P.M.

Vice-President R. D. Beatley, presiding

1. ADDRESS—"The Geometry of Inversion." Professor Roger A. Johnson, Brooklyn College.
2. ADDRESS—"Graphical Methods in Mathematics." Professor George W. Mullins, Barnard College, Columbia University.

Adjourned Annual Meeting of the National Council—4 P.M.

It was moved and carried that the policy of three meetings a year; one in July with the N.E.A., one in December with the A.A.A.S., and the annual meeting in February with the Department of Superintendence of the N.E.A. be adopted as a policy of the Council. Miss Martha Hildebrandt presented the following resolution; "Resolved that the National Council of Teachers of Mathematics favors the inclusion in the legal requirement for those persons who are teaching mathematics in secondary schools of an approved minimum of preparation in the subject-matter of mathematics." The motion to adopt this resolution as a policy of the Council was made and carried. The meeting adjourned.

Annual Banquet

The Annual Banquet of the National Council was attended by 143 members and guests. At the speakers' table little regular tetrahedrons were used effectively as place cards. President J. O. Hassler presented as the speaker of the evening Professor C. J. Keyser, of Columbia University, who gave a very interesting and inspiring address on "Mathematics and the Dance of Life." Mrs. Keyser was presented to the audience as well as Mr. Burton W. Lidell, Chairman of the Local Committee. Mr. Lidell then presented the individual members of his committee; Charles L. Werntz, Bertha Stanburg, Samuel Gillingham, Gertrude M.

Brennan, Mabel Rhodes, Mary Laws, Lloyd Spangler, Mary Spencer, and Anna Sailor. Secretary Schreiber made a brief report as to the attendance at this 16th annual meeting stating that 179 had registered from 20 different states. He asked those to rise who had attended the annual meeting in Atlantic City in 1930, and the first Atlantic City meeting in 1921, and then also the charter members who attended the first meeting in Cleveland in 1920 when the National Council was organized. W. D. Reeve asked all those in attendance to sign their names to a letter sending greeting to Professor H. E. Slaught who was unable to attend the meeting because of illness. A telegram to Professor Slaught was sent by the secretary. The 16th annual meeting adjourned.

THE NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS
REPORT OF THE TREASURER FOR THE YEAR
FEBRUARY 1, 1934–FEBRUARY 9, 1935

Balance on hand at beginning of year—			
Union National Bank of Macomb, Ill.		$1270.34	
Savings Bank deposit		522.01	
New York Telephone bond, 4½, 1939		982.88	
Commonwealth Edison Bond, 5, 1953		931.89	
Accrued Book Value of Bonds		3.75	
			$3710.87
Receipts for the year			
W. D. Reeve, Yearbooks	$ 201.00		
Mathematics Teacher	987.38		
Bureau of Publications		$1188.38	
Yearbooks		199.05	
($1392.30 credit towards 10th Yearbook)			
Interest on Bonds		94.25	
Interest on Savings		13.88	1495.56
			$5206.43
Expenditures for the year—			
Annual Meeting:			
Directors' Expenses	$ 571.06		
Speakers	153.71		
Local Committee	47.10		
Printing	8.55	$ 780.42	
Pittsburgh Meeting:			
Directors' Expenses	$ 141.00		
Speakers	55.00		

Local Committee	20.84	216.84	
Policy Committee		5.00	
Office of Sec.-Treas.			
Stationery	$ 39.29		
Postage, Supplies, etc.	95.33		
Recording Fee	1.30		
Tax on checks	.74		
Secretary Service	400.00	536.66	1538.92
			$3667.51

BALANCE SHEET, FEBRUARY 9, 1935

Assets:		For 1934
Commercial Bank Deposit	$1118.85	$1270.34
New York Telephone Bond	984.53	982.88
Commonwealth Edison Bond	933.99	931.89
Savings Bank Deposit	630.14	522.01
Total Assets	$3667.51	$3707.12

Liabilities:
None

(Signed) Edwin W. Schreiber, Treasurer

The above account has been audited and found correct.

(Signed) W. S. Schlauch, Auditor

ATTENDANCE

Colorado (1)

Denver
Flannery, Ruby S. (R) East High

Connecticut (2)

Hartford
Wheeler, Dorothy S. (R) Bulkely High

New Britain
Waggoner, Sherman G. (W) Teachers College of Connecticut

District of Columbia (6)

Washington
Chase, Valene (G) Terrill Jr. High
Grubbs, Ethel Harris (R) High schools divisions 10–13
Hullips, Myrtle (W) Howard Univ.
Mayer, Willa (Mrs.) (W) Administration Building
Murray, George (G) Armstrong High
Payne, Gladys P. (R) Garnet-Patterson Jr. High School

Illinois (4)

Chicago
Johnson, J. T. (B) Chicago Normal College

Macomb
Schreiber, Edwin W. (B) Western Illinois State Teachers College

Maywood
Hildebrandt, Martha (B) Proviso Township High School

Winnetka
Washburne, Carleton (G) Superintendent of Schools

Iowa (1)

Cedar Falls
Kearney, Dora (B) Iowa State Teachers College

Kentucky (1)

Lexington
Mathis, Buena (W) Bryan Station

Maryland (2)

Baltimore

Herbert, Agnes (R) Clifton Park Jr. High School

Roche, Nanette (R) Junior High School Supervisor

Massachusetts (7)

Boston

Buckingham, Burdette (R)

Flaherty, Anna (W) Jamaica Plain High

Kee, Olive (R) Teachers College

Stevens, Ernest (R) Ginn & Co.

Wilson, Guy (R) Boston University

Cambridge

Beatley, Ralph (R) Harvard Graduate School of Education

Springfield

Smith, Rolland (R) Classical High

Michigan (6)

Ann Arbor

Schorling, Raleigh (B) Univ. of Michigan

Detroit

Sauble, Irene (R)

Thiele, C. L. (B) Detroit Public Schools Supervisor

Wolber, Joseph G. (W) Northwestern High School

Worden, Orpha E. (B) Wayne Univ.

Kalamazoo

Everett, John P. (B) Western State Teachers College

Minnesota (2)

Minneapolis

Brueckner, L. J. (R) Univ. of Minnesota

Wolsey, Edith (R) Sanford Jr. High

Missouri (3)

Kirksville

Jamison, G. H. (R) State Teachers College

McClure, C. H. (G) State Teachers College

Pemberton, W. S. (R) State Teachers College

Nebraska (1)

Lincoln

Congdon, Allan (R) Univ. of Neb.

New Jersey (44)

Atlantic City

Bank, Melvin (G) Atlantic City High

Burt, Blanche (G) Atlantic City High

Gill, Norman (G) Atlantic City High

Hollenbach, Marie (G) Atlantic City High

Laws, Mary K. (G) Atlantic City High

Lidell, Burton (R) Atlantic City High

Marshall, Anne (G) Atlantic City High

Mason, Harry (G) Atlantic City High

Meiler, James (G) Atlantic City High

Risley, William (G) Atlantic City High

Smith, Bettie Jean (G) Atlantic City High

Snyder, Alan (G) Atlantic City High

Snyder, Carolyn (G) Atlantic City High

Spencer, Mary (R) Atlantic City High

Stanburg, Bertha (R) Atlantic City High

Weinberg, Alan (G) Atlantic City High

Werntz, Charles (R) Atlantic City High

Belleplain

Durell, Fletcher (R)

Durell, (Mrs.) Fletcher (G)

Camden

McCobb, Robert (W) Hatch Jr. High

East Orange

Mallory, Stan (G) East Orange High

Robinson, Fannie (W) East Orange High School

Elizabeth

Carroll, Margaret (R) Junior High School, No. 4

en, Armanda (R) Jefferson High

Hillside
Ellis, Bart (G) Hillside High

Jersey City
Grossnikle, F. E. (R) State Normal
McMackin, Frank (W) Dickinson High

Montclair
Hildebrandt, E. H. C. (W) State Teachers College
Fehr, Howard (R) State Teachers College
Mallory, Virgil (R) State Teachers College
Stone, John (R) State Teachers College

Mountain Lake
Schofield, Hayden (W) Public School

Newark
Conklin, R. P. (R) Central High
Dickey, John (W) State Normal School
Mandeville, Marjorie (R) Silver Burdett Publishers
Plenty, Jane (R) State Normal School

Orange
Kimm, W. I. (G) Ginn & Co.

Ridgewood
Powell, Nell (W) Ridgewood High

Summit
Shuttlesworth, Joseph (R) Summit High

Trenton
Paxton, Anna (W) State Teachers College
Schuster, C. N. (W) State Teachers College

Ventnor City
Pyle, Estelle J. (G) Ventnor Ave.

Verona
Cork, Imogene (W) Verona High

Westfield
Hewitt, Annie (W) Senior High

New York (58)

Alfred
Seidlin, Joseph (R) Alfred Univ.

Bridgehampton
Zakary, Robert (W) Bridgehampton High

Brooklyn
Cogin, Lena (G) Public School 173
Harris, Louise (W) Manual Training High School
Lazar, Nathan (W) Alexander Hamilton High
Shanholt, Henry (W) Abraham Lincoln High
Shapiro, Aaron (W) Alexander Hamilton High

Buffalo
Bull, Harriet (W) Fosdick-Masten High
Crofts, Mary (R) Supervision
Kenny, Mary (W) East High
Podmele, Theresa (R) East High

Garden City
Holton, Chandler (G) Cherry Valley High
Rhoad, D. L. (W) Garden City High

New York City
Atherton, Charles (R) New College, Columbia
Austin, Mary (W) Evander Childs High
Badanes, Saul (W) Public School 173
Bergstresser, Clinton (W) Jamaica High School
Clark, John (B) Lincoln School
Clifford, Paul (R) Columbia Univ.
Corcoran, Mary (W) Teachers College, Columbia
Derney, Anne (W)
Duffy, Mary (G) Public School 189M.
Eidel, Ellen (W) Teachers College, Columbia
Fuller, Kenneth (W) College of the City of New York
Goulding, Charles (W) Birch Wathen
Greenberg, Etta (W) Washington Irving High

Nellenbargen, Marion (W) Teachers College Student
Hertim, Lillian (W) New College Columbia
Johnston, Margaret (W) Teachers College, Columbia University
Kaufman, Irma (W) Dalton School
Keyser, C. J. (G) Columbia University
Keyser, Sarah (G) Nightingale-Bainford
McCormack, Joseph (R) Theodore Roosevelt
Neumeister, Mildred (G) Washington Irving
Orleans, Joseph B. (R) George Washington
Palmer, Maritta (R) Jr. High School
Reeve, W. D. (B) Teachers College, Columbia
Roll, Rose (W) Washington Irving
Rose, A. B. (W) Newtown High
Schlauch, Wm. (R) New York Univ.
Short, Alice (W) Teachers College, Columbia
Stabler, Russell (R) Dwight School
Sutherland, Ethel (W) Teachers College, Columbia
Upton, C. B. (R) Teachers College
Weston, Virginia (W) Teachers College, Columbia
Wood, La Vergil, (W) Horace Mann
Wood, Meta (R) Hunter College

Oneonta
Sanford, Vera (B) State Normal School

Queens Village
Hendrie, Wm. (G) 109

Rochester
Betz, William (B) Public Schools

Rockville Center
Reeve, Alice (R) South Side High

Scarborough
Mattern, Roy (R) Scarborough

Syracuse
Dence, C. J. (R) Central High

Tarrytown
Bedford, Fred (R) Tarrytown
Bedford, (Mrs.) Fred (R)

Valley Stream
Henry, Etta (R) Central High

Woodmere
Babcock, Lester (R) Woodmere Acad.

Yonkers
Otis, Arthur (R) World Book Co.

North Carolina (1)

Greenville
Barker, Herbert (R) East Carolina State Teachers College

Ohio (8)

Athens
Benz, H. E. (R) Ohio University
Morton, R. L. (B) Ohio University

Columbus
Adel, Edna (G) Fulton
Morningstar, Charlotte (R) North High School
Coulter, L. E. (W) Theodore Roosevelt
Fawcett, Harold (R) University High School. Ohio State University
Gugle, Marie (B) Ass't. Superintendent of Schools

Oxford
Christofferson, H. C. (R) Miami Univ

Oklahoma (1)

Norman
Hassler, J. O. (B) University of Oklahoma

Pennsylvania (29)

Abington
Woodruff, J. S. (R) Abington High

East Stroudsbury
May, Jonas T. (W) State Teachers College

New Castle
McCune, Sara (R) New Castle Sr. High

Philadelphia
Axler, Isadore (G) Temple Univ.

Bechtel, John C. (R) South Phila. High for Boys
Briskin, Isadore (G) Temple Univ.
Briskin, Nathan (G) Temple Univ.
Carl, Elmer H. (W) Olney High
Carroll, Isadore, (G) Temple Teachers College
Constable, Mary (R) Phila. High School for Girls
Darnell, Alice (R) Germantown Friends School
Dordick, Oscar (G) Temple Univ.
Fogg, P. M. (W) Oak Lane Country Day School
Fogg, (Mrs.) P. M. (G)
Goodman, Wm. (G) Temple Univ.
Holbrook, Alice (R) High School for Girls
Mantz, Ephram (G) Temple Univ.
Pollack, Richard (G) Temple Univ.
Reilly, Margaret (W) Woodrow Wilson Junior High
Root, Mary (W) Wm. Penn. High School
Rorer, Jonathan (R) Wm. Penn. High School
Sapolsky, Benj. (G) Temple Univ.
Stillman, Ben. (G) Temple Univ.
Stokes, C. N. (B) Temple Univ.
Sternberger, Jesse (G) Temple Univ.
Wood, Elizabeth (R) Kensington High
Wyatt, Ruth (R) Woodrow Wilson Jr. High

Trexlertown
Kunkel, Paul (W)

West Chester
Humphreys, Roland (W) State Teachers College

Washington (1)

Bellingham
Bond, Elias (W) State Teachers College

Wisconsin (1)

Racine
Potter, Mary (B) Supervisor of Maths

ATTENDENCE BY STATES

	G.	W.	R.	B.	Total
1. Colorado	0	0	1	0	1
2. Connecticut	0	1	1	0	2
3. District of Columbia	2	2	2	0	6
4. Illinois	1	0	0	3	4
5. Iowa	0	0	0	1	1
6. Kentucky	0	1	0	0	1
7. Maryland	0	0	2	0	2
8. Massachusetts	0	1	6	0	7
9. Michigan	0	1	1	4	6
10. Minnesota	0	0	2	0	2
11. Missouri	1	0	2	0	3
12. Nebraska	0	0	1	0	1
13. New Jersey	18	11	15	0	44
14. New York	7	27	20	4	58
15. North Carolina	0	0	1	0	1
16. Ohio	1	1	4	2	8

17. Oklahoma	0	0	0	1	1
18. Pennsylvania	12	7	9	1	29
19. Washington	0	1	0	0	1
20. Wisconsin	0	0	0	1	1
	42	53	67	17	179

Code: G.—Visitor or guest.
W.—Member attending his first annual meeting.
R.—Member attending 2–7 annual meetings.
B.—Member attending eight or more annual meetings.

On to Colorado!

"Git along, little doggie, git along." The great 1935 round-up of the N.E.A. officially scheduled for one short week in July, will, for thousands of teachers, become an all-summer, all-Colorado vacation. For Denver is the heart of the world's great vacation land.

Two national parks are located in Colorado. The Rocky Mountain National Park, of which Estes Park is perhaps the best known spot, is only 90 miles from Denver. A one-day motor trip takes the traveler through Estes Park via magnificent cañons, Grand Lake, with its "highest yacht club of the world," and two continental divides.

Seventy-five miles south of Denver is the Colorado Springs region, famous for Pike's Peak and the Garden of the Gods. From Colorado Springs, the motorist may drive by way of scenic Corley highway or Ute Pass to Cripple Creek, the one-time famous mining center of the state.

If a longer motor trip is desired, the convention goer may wish to drive to the Mesa Verde, land of the Aztecs, in southwestern Colorado. Here, the homes of the Cliff Dwellers of two thousand years ago may be entered. The country offers no more magnificent scenery than that which may be seen on the trip to this mesa. The world-famous million-dollar highway is part of the route.

For further information or photographs write to A. Helen Anderson, supervisor of publications, Denver Public Schools, Denver, Colorado.

Notice

Will any reader of The Mathematics Teacher who has a copy of the November 1931 issue for sale please communicate with Miss Katharine Leonard of Moorhead, Minnesota?

Predicting Achievement in Plane Geometry

By H. D. RICHARDSON
Director of Research
Deerfield-Shields Township High School
Highland Park, Illinois

IT IS GENERALLY conceded by mathematics teachers and school administrators that all students who now attend the secondary school should not be required to study plane geometry. This position rests upon the belief that many of the students who now come to high school possess neither the ability necessary to succeed in the subject nor the capacity to profit greatly from its content. The experience of numerous students who have pursued the subject only to fail at the end serves to substantiate the contention of teachers that many do not possess the requisite ability. The increasing number of such unfortunate experiences has led to a search for means that might be used in identifying those students most likely to find the subject least fitted to their needs and abilities.

The general practice of requiring a passing grade in algebra as a prerequisite for geometry has served to screen out many who have diminished aptitude for algebra, but it remains an unsettled question as to whether this is a valid method for discovering those who possess the ability to pursue plane geometry successfully. It is well known that many who pass algebra fail to pass geometry. It is not so well known whether there are many who have failed to pass algebra who would succeed with geometry. At any rate, a passing grade in algebra is far from a perfect predictive measure of success in geometry, although it is a significant one.

Many have looked to mental test results to furnish an adequate index of ability to succeed in secondary school subjects, including geometry. A number of studies have shown that intelligence test results are in general no better than algebra grades for purposes of predicting success in geometry. Indeed, in several instances they were less significant.[1] It is no doubt true that ability to suc-

[1] Brooks, Fowler D., *The Psychology of Adolescence*, Houghton Mifflin Company New York, 1929, p. 568.

ceed in geometry requires considerable mental ability, but it seems from the studies reported that this requirement is met only to a limited extent by high mental test scores. While the relationship between intelligence test results and geometry achievement is positive and appreciable, the intelligence factor alone is by no means a reliable index of ability to succeed in geometry.

Of late, attempts have been made to construct tests that tap more completely the abilities associated with success in geometry than do the general mental tests. Recent reports of the use of two such aptitude or prognostic tests in plane geometry show promising results.[2,3] The remainder of this paper reports a further study of the significance of results from one of these tests, and a number of other factors for predicting success in plane geometry.

The Prognostic Test Data

In the spring of 1932, the Orleans Geometry Prognosis Test was administered to all second semester algebra students in the Deerfield-Shields Township High School who expected to register for geometry the following September. The results on this test were used along with mental test results, first semester algebra grades, and teacher's estimate of ability to do geometry, in advising students concerning registration for plane geometry. No student was denied registration in geometry because of a low rating on the prognostic test, but an individual with uniformly low ratings in all of the above factors, was advised to postpone or omit geometry and to take some other subject instead. At the end of the first semester, February 1933, the grades of the 122 who registered for geometry were correlated with the prognostic test scores. The resulting correlation coefficient of $.58 \pm .04$ indicated a substantial relationship. Certain factors, such as the homogeneity of the group and the unreliability of the grading system, tended, no doubt, to reduce the size of the coefficient.

This reasonably high relationship between a single factor (prognostic test scores) and geometry achievement in terms of semester grades, seemed to warrant further study of the use of this test and

[2] Orleans, Joseph B., "A Study of Prognosis of Probable Success in Algebra and in Geometry," *The Mathematics Teacher*, 27: 165–180; 225–246, April and May, 1934.

[3] Lee, J. Murray and Hughes, W. Hardin, "Predicting Success in Geometry," *The School Review*, 42: 188–196, March, 1934.

other factors which might prove to have predictive significance, and which when combined with the prognostic test results might add greatly to their prognostic value or power. Accordingly it was decided to give the Orleans Geometry Prognosis Test to all of the 1933 second semester algebra students and use the results for registration purposes as described above for the 1932 group, and in addition, to select for experimental purposes several factors of possible prognostic value to correlate with semester grades in geometry in February, 1934.

TABLE 1

Distribution of Scores
Orleans Geometry Prognosis Test
233 Ninth Grade Algebra Students, February, 1933

Score	Did Not Register for Geometry		Registered for Geometry				Total
			Not Included in Study		Included in Study		
	Not Recom.	Recom.	Not Recom.	Recom.	Not Recom.	Recom.	
150						1	1
140						3	3
130				2		8	10
120		3				12	15
110		8				13	21
100		4		3		18	25
90		8		7		21	36
80		5		4		21	30
70		3	2	3	1	24	33
60	9	3	2		2	6	22
50	10	1			1	2	14
40	16	1				1	18
30	4						4
20					1		1
	39	36	4	19	5	130	233
	75		23		135		

The Orleans Prognosis Test was given to all second semester algebra students in February, 1933. Of the 233 students who took the prognostic test 48, or approximately 20%, were advised not to register for geometry. Some were advised to postpone taking the subject for a year and others were advised to omit it entirely from their programs. In the fall of 1933, 158 students were enrolled in geometry classes. Of the 158, nine had not been recommended. Of the 75 who did not enter geometry classes 39 were not recommended. The 75 who did not enter geometry were registered in

commercial arithmetic or general mathematics. Data on eight factors thought to have prognostic value were available for 135 of the 158 who entered geometry classes, and consequently the records of these 135 beginning geometry students, including 5 not recommended, were used for this study. Table 1 presents the total distribution of scores of those who took the prognostic test, and separate distributions for those who were or were not recommended, did or did not register for geometry, and were or were not included in the present study.

Factors Studied for Their Predictive Significance

A brief consideration of each of the eight factors selected for investigation in view of their probable significance for predicting geometry achievement in terms of first semester grades follows:[4]

1. How significant are scores on the Orleans Geometry Prognosis Test for preditcing first semester geometry grades when the test is administered to second semester algebra students?

2. Can the algebra teacher, early in the second semester on the basis of observation and understanding of the work done in algebra, predict a student's first semester grade in geometry? To answer this question each algebra teacher was asked to estimate the most probable first semester geometry grade of each student in his class.

3. Are first semester algebra grades closely enough related to first semester geometry achievement to warrant their use as a predictive factor?

4. Is achievement in algebra, as shown by second semester grades, a significant factor in predicting first semester achievement in geometry?

5. Can scores on the Iowa Algebra Aptitude Test, administered near the end of the 8th grade, be used a year later in predicting achievement in first semester geometry? Scores on this test were used with other data to place students in ability groups in algebra. Can the same data be used to advantage in predicting geometry achievement?

[4] Semester grades were used as the achievement criterion in plane geometry. Standardized achievement test scores are often used as an achievement criterion. However, it is the final grade that becomes a part of the student's permanent record that teachers use to measure achievement and it is success or aptitude so measured that we are trying to predict.

6. The Terman Group Test of Mental Ability was administered to 8th grade graduates and used with other data for placement and sectioning in freshman subjects. Can this group test I.Q. be used a year later in predicting first semester geometry grades?

7. If semester grades in geometry are not pure measures of achievement but are conditioned by effort, quality and neatness of prepared daily work, possibly ratings on a personal trait defined to include these qualities would prove to be a pertinent predictive factor. To test this possibility algebra teachers were asked to rate each student along a 5 point scale on STUDIOUSNESS—as exhibited through quality and excellence in preparation of daily assignments in mathematics. The algebra teacher made this rating at the time the first semester geometry grade was estimated for each student.

8. With the information described in items 1 to 7 above at hand how well can the Director of Research predict first semester geometry grades? To answer this question, the Director of Research attempted to predict the first semester geometry grade of each student on the basis of a composite judgment formed after weighing empirically this information.

TABLE 2

Correlations of the Eight Predictive Factors With Geometry Achievement Measured by First Semester Grades—135 Students

Factors	No.	Correlation
Second Semester Algebra Grades	(1)	.702 ± .030
Teacher's Estimate	(2)	.672 ± .032
Orleans Geometry Prognostic Test Scores	(3)	.669 ± .032
Research Office Prognosis	(4)	.637 ± .034
First Semester Algebra Grades	(5)	.625 ± .035
Iowa Algebra Prognostic Test Scores	(6)	.504 ± .043
Terman Group Mental Test I.Q.'s	(7)	.501 ± .043
Teacher's Rating on Studiousness	(8)	.338 ± .052

THE PREDICTIVE VALUE OF THE FACTORS SINGLY AND IN COMBINATION

The predictive significance of each of these factors was determined by correlating each with the grades earned in geometry at the end of the first semester. The correlations are shown in Table 2. Second semester algebra grades correlate .70 with first semester geometry grades, and are the best single predictive factor. Teacher's estimate and prognostic test scores are equally good; each cor-

relates .67 with the criterion. The research office prognosis correlates .64 and is only slightly better, for predictive purposes, than are first semester algebra grades which correlate .63. The algebra prognostic test scores and the I.Q.'s are equal in predictive value, but correlate only to the extent of .50 with geometry achievement. Finally, teacher's ratings on studiousness correlate .34 with first semester geometry grades.

TABLE 3

Intercorrelations of the Five Most Promising Factors Used to Predict Geometry Achievement Measured by First Semester Grades

Factors		0	1	2	3	4
First Semester Grades in Geometry	0	—				
Second Semester Algebra Grades	1	.702				
Teacher's Estimate	2	.672	.814			
Orleans Geometry Prognostic Test Scores	3	.669	.687	.614		
Research Office Prognosis	4	.637	.535	.577	.899	
First Semester Algebra Grades	5	.625	.771	.783	.585	.533

The first five of these correlations are reasonably high. Although the factors appear quite similar and may represent to a considerable extent the same abilities, it is possible that some are sufficiently diverse so that when combined they will yield a yet greater predictive coefficient. The intercorrelations of these five factors shown in Table 3 indicate that some combinations are possible. It will be seen that second semester algebra grades, teachers estimates, and first semester algebra grades correlate highly. So also do geometry prognostic test scores and research office predicted grades. On the other hand, the correlation between second semester algebra grades and geometry prognostic test scores is lower than is the correlation of either with first semester geometry grades. This means that combined properly these two factors together will predict semester grades in geometry better than will either one alone. The multiple correlation technique was used to give the combined predictive power of these two factors. The resulting multiple correlation coefficient is .805 which is decidedly higher than the coefficients obtained from using either factor alone. Similarly second semester algebra grades and research office prognosis when combined yield a multiple R of .767, and teacher's estimates and geometry prognostic test scores together give a multiple R of .746. These are large enough increases in the coefficients to warrant the use of both factors if predictions are to be made.

To take full advantage of the predictive power of these factors in combination requires the use of the regression equation technique. This technique presents some difficulties to the average adviser or counselor, and the technique has certain limitations in practical use. Therefore, it seems best to devise a more simple means for using these two factors in combination for every day guidance or registration purposes. The regression technique gives each factor an optimum weight and hence its greatest predictive power. For practical purposes these two factors can be given equal weight, and although some of their predictive power will be lost it will still be greater than when either factor is used alone. Thus, when second semester algebra grades and geometry prognostic test scores are given equal weight in combination the predicting coefficient is .77 instead of .805.[5]

The Practical Use of the Two Best Predictive Factors

The practical use of these two factors for predicting geometry achievement can best be shown by charting graphically actual achievement in terms of first semester grades in relation to the two factors. This is done by making a scattergram which shows the grade earned by each individual in relationship to his standing or rank on the two factors. Such a scattergram is shown in Table 4 for the 135 students of this study. The vertical scale on this chart measures the grade earned in second semester algebra. The grades are expressed in numerals from 0 to 5. Zero is a failing grade; 5 is the highest grade. On the horizontal scale of the chart are laid off the scores on the geometry aptitude test. In the squares or boxes of the chart are the semester geometry grades for each individual in relation to the two factors measured on the vertical and horizontal scales. For example, in the box or square corresponding to grade 3 on the vertical scale and score 100–109 on the horizontal scale there are semester geometry grades of seven individuals,—six of whom had a grade of 3 and one of whom had a grade of 1. A study of this chart will show that actual achievement is in general rather closely related to the two predictive factors, and hence, a chart similar to

[5] The method used to compute the correlation when the two variables are weighted equally is that described by Symonds in an article entitled "A Foreign Language Prognosis Test" which appeared in the *Teachers College Record* for March 1930.

TABLE 4

First Semester Geometry Achievement in Relation to Second Semester Algebra Grade and Orleans Geometry Prognosis Test Score—135 Students

Second Semester Algebra Grade	Orleans Geometry Prognosis Test Score													Number
	20–29	30–39	40–49	50–59	60–69	70–79	80–89	90–99	100–109	110–119	120–129	130–139	140–149	150–159	
5									5 4	5 4	5 **Area V**		4 4	5	8
4							2	3	4 **Area IV**	5 3	555 433	4 4	5		14
3				2	2 **Area III**	4 33 1	4 222 222 3	33 22 22 1	33 33 33 1	5 44 3	4 33 22	44 44 3			42
2		X **Area II**	1 XXX	2 XX XXX	**0*** 123 23 XXXX	1111 **1***22 222 0 4	111 111 222	0 3 111 222 333	222 22 3	1 3 444		3			52
1	**0*** **Area I**	XX X	XXX XXX XXX	**0*** XXX	**2*** XX	00 00 1 2	1	1 3	1 2						14
0			XX XX	XX	XXX	00 2	1 2								5
Number	1		1	3	8	25	21	21	18	13	12	8	3	1	135

The numbers in the scattergram are the first semester geometry grades.

* Not recommended, but registered and included in this study.

X Not recommended, not registered, and not included in this study.

this could be used to *predict* achievement instead of *recording* achievement.

Further practical value of this device may be shown by studying several different areas of this chart in terms of the differentiating power of the two factors. Consider Area I to include through 1 on the vertical scale and to 80 on the horizontal scale. Similarly, Area II includes 2 on the vertical scale and 80–89 on the horizontal; Area III, 3 vertical, 90–109 horizontal; Area IV, 4 vertical, 110–129 horizontal; and Area V, 5 vertical and 130 and above horizontal. The differentiating power of the predictive factors from area to area may be seen from the data of Table 5. Sixty-six per cent of the grades in Area I are failing grades; 75% are 0 or 1; and 25% are 2 or higher. Grades below 2 are not college recommending grades. It would appear that a student whose grade in algebra is 1 or 0 and whose score on the geometry aptitude test is below 80 has 1 chance in 4 of getting a college recommending grade in the subject.[6] The scores on the two predictive factors that determine the boundary line of this area may be called the "critical scores." In other words, students earning scores on the two predictive factors below these critical scores may be regarded as poor "risks," and

TABLE 5

The Differentiating Power of the Two Predictive Factors Defined in Terms of Five Areas of the Scattergram—135 Students

	Number Earning Grades						Per Cent in Each Area Earning Grades		
	0	1	2	3	4	5	0	0 and 1	2 and Above
Area V				2	10	5	0%	0%	100%
Area IV		1	3	8	8	5	0%	4%	96%
Area III	1	8	21	17	2		2%	17%	83%
Area II	2	14	12	2			7%	53%	47%
Area I	8	1	3				66%	75%	25%

may well be advised to take some subject in place of geometry. Area II becomes a "doubtful" area. The chances are about even that a student with an algebra grade of 2 and a geometry prognostic test score of 80–89 will earn a college recommending grade. Stu-

[6] These chances are based on achievement results of the students who actually registered for geometry. Had all students who had taken the prognostic test actually registered for the subject (see Table 1), the percentage of 0 and 1 grades in Areas I and II would doubtless have been even greater.

dents whose scores on the predictive factors place them in the remaining Areas are good "risks" for geometry and should be encouraged to register for the subject. This scattergram becomes a useful device for counseling and registration purposes once the predictive values of the factors are known in terms of their discriminating or differentiating power.

It will be recalled that earlier in this paper it was mentioned that 5 of the students used in this study were advised not to register for geometry. It may be of some little interest to know what grades they earned. They are shown on the chart in Table 4 by the asterisks. Three failed, one received a grade of 1, and the other received a grade of 2—a bare college recommending grade. Further, it will be recalled that 39 individuals not included in this study were advised not to take geometry and followed that advice. Their positions on the chart in terms of their predictive scores are shown by X's. Thirteen fall in the doubtful Area II, and 26 fall in Area I, well below the critical scores. Inasmuch as a number of these students were advised merely to postpone the subject and none were prohibited from taking it, one concludes that relatively little injustice was done as a result of this advice. Nevertheless, one charged with the responsibility of advising with these individuals cannot afford to be too dogmatic or prescriptive, and on the other hand he cannot afford to disregard the facts. It is for this reason that continuous studies of this character need to be made by those charged with advisory responsibilities.

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Reduction of Angles in Trigonometry

By EDGAR DEHN
Columbia University, New York, New York

I WANT TO explain in this article a rule for reducing angles which I have used in my classes for many years.

Suppose the work of the term began with the definition of trigonometric functions for both small angles in right triangles and large angles in a circle. If the work did not begin this way, the deduction of my rule would have to be modified but slightly.

Draw a circle, divide it into quadrants and take an angle α ending, say, in the second quadrant. Mark the abscissa and ordinate of the terminal point, as I call the end on the circle of the terminal line, and let the ordinate be a, the abscissa $-b$ and the distance c. To the acute angle between the terminal line and the x-axis refer as the X-angle, to the acute angle between the terminal line and the y-axis as the Y-angle.

Outside of the circle, draw a triangle congruent to the one in the second quadrant of the circle. Its sides are a, b and c, the minus having disappeared with accepted directions. Its angles are the X-angle and the Y-angle.

From the circle we have

$$\sin \alpha = \frac{a}{c}, \quad \cos \alpha = -\frac{b}{c}, \quad \tan \alpha = -\frac{a}{b}.$$

Keeping the signs of the right members and replacing the ratios by functions obtained from the triangle, we have

$$\sin \alpha = \frac{a}{c} = \sin X = \cos Y$$

$$\cos \alpha = -\frac{b}{c} = -\cos X = -\sin Y$$

$$\tan \alpha = -\frac{a}{b} = -\tan X = -\cot Y.$$

From this we read the rule:

Given the function of a large angle, we can replace the large angle by the X-angle keeping the function or by the Y-angle changing to the cofunction.

The result is plus or minus according to the sign of the original function.

The rule is so simple that after a few problems worked out on the board the students can do the reduction in their minds.

Most any reduction can be effected by this rule, for example

$$\sin (90 + \alpha) = \cos \alpha$$

when α is small; and the result can be verified for any α.

I have found my rule to work exceedingly well in class. It may not be accepted, but I submit it as a matter of record.

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The following issues of the *Mathematics Teacher* are still available and may be had from the office of the *Mathematics Teacher*, 525 West 120th Street, New York

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NEWS NOTES

PROFESSOR EARLE R. HEDRICK of the University of California at Los Angeles will give two courses in mathematics this summer at Teachers College, Columbia University. One course will deal with professionalized subject matter in algebra and geometry. It will treat those topics in elementary algebra and geometry that offer peculiar difficulty to teachers. The other course will deal with the teaching of mathematics in junior colleges and in lower divisions of colleges and universities. Here an attempt will be made to study the pedagogical questions that arise in instruction in college algebra, trigonometry, analytic geometry, and the calculus.

"MATHEMATICS ON THE OFFENSIVE" is the title of a talk given by Dean E. J. Moulton of Northwestern University to the Men's Mathematics Club of Chicago on March 15, 1935. Copies of this interesting talk may be had postpaid by sending 21¢ to W. Gorsleice, 5286 Huron St., Chicago, Ill.

The High School Mathematics Section of the Oklahoma Education Association held its annual meeting in Tulsa on Friday, February 8, 1935. Mrs. Alta Carder of Cordell was chairman of the group, and E. C. Intallube of Oklahoma City was secretary.

The program follows:

Greeting from the National Council—Dr. J. O. Hassler.

Modern Solid Geometry—Dr. N. A. Court.

Theme: The use of the text book in the Teaching of Mathematics.

Panel Discussion:

Question 1. How may the text be used in teaching seventh and eighth grade mathematics?—Miss Margaret Thompson, Oklahoma City, Discussion leader.

Question 2. How may the text book be used in teaching algebra?—L. W. Lavengood and other teachers from Tulsa.

Question 3. How may the text be used in teaching geometry?—Marian Van Griethuysen, Elk City; Winifred Robbins, Clinton; Mabel Cranmer, Weatherford.

Legislative problems—L. S. DeMand, Central High School, Oklahoma City.

Business Session.

The most important feature of the business session was the adoption of a motion authorizing the incoming officers to appoint a Policy Committee which should have the task of formulating a definite program for the improvement of the teaching of mathematics in the secondary schools in Oklahoma.

ARRANGEMENTS have now definitely been made for the synchronized conferences of the World Federation of Education Associations, the International Federation of Secondary Associations and the International Federation of Teachers' Associations (elementary), to be held at Oxford, England, from 10th to 17th of August, 1935.

The program of subjects to be discussed at the various meetings will be very comprehensive, and cover most of

the problems connected with teaching and education generally. In addition to the usual social functions and excursions, an educational exhibition of English school work will be arranged for the benefit of both English and Foreign visitors.

This meeting promises to be not only of unique character, but also of historic importance, and those who attend will have opportunities for contacts with educationists and teachers from many lands.

Plans are being worked out for tours of various lengths and costs throughout the British Isles and also on the continent. Persons who are interested in sailing dates, cost of travel, accommodations, etc., should write to the headquarters office of the World Federation, 1201 Sixteenth Street, N.W., Washington, D.C.

THE Calcutta Mathematical Society has announced for the subject of the first competition for the "Krishna Kumari-Ganesh Prasad Prize and Medal" the following:

"Lives and works of the ten famous Hindu Mathematicians; Aryabhatta, Varamihir, Bhaskara I, Lalla, Bramhagupta, Sridhar, Mahavir, Sripati, Bhaskara II, and Narayana." (Spellings as in the announcement.)

No country has of late given more attention than India to the historical development of its mathematics, and the publication of the results of this competition will be awaited with great interest.

Mathematics Education Field Course in Germany Summer of 1935

TEACHERS COLLEGE, Columbia University, offers in the summer of 1935, a field study course in Mathematics Education in Germany. This course will provide teachers and students of mathematics an opportunity to study at first-hand mathematics and mathematics education in all types of German schools and universities. The group will sail from New York about June 20 and will sail from Hamburg on the return trip on August 10th. The total cost including passage from New York to New York will be $550.00, to cover all necessary expenses except tips on the boat, passport, personal expense, and amusements. This cost includes the University fee and four points of tuition. Additional points of credit is at the rate of $10.00 a point.

For further information address:

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